

National Grid and transmission losses

AQA GCSE Combined Science Trilogy 8464 and Separate Physics 8463 | Paper 1 | Both tiers

Worked answers and marking guidance | 28 parts | 48 marks

Specification points covered

8463 4.2.4.3 / 8464 6.2.4.3: National Grid, transformer roles and efficient transmission

8463 4.2.4.1 / 8464 6.2.4.1: electrical power, $P = VI$ and $P = I^2R$

8463 4.2.4.2 / 8464 6.2.4.2: energy transferred, $E = Pt$ (selected content)

A grid operator plans a link from offshore wind generators to a coastal town. Use a pilot trial and two proposed cable routes to decide how to reduce unwanted heating.

Original PhysicsUK GCSE practice, not an official AQA paper or mark scheme. Green diagram labels give the answers. Credit equivalent correct reasoning and sensible error carried forward.

1 From the wind farm to the town

Figure 1 is a simplified energy-transfer chain. Distribution includes several stages; the diagram is not a circuit diagram.

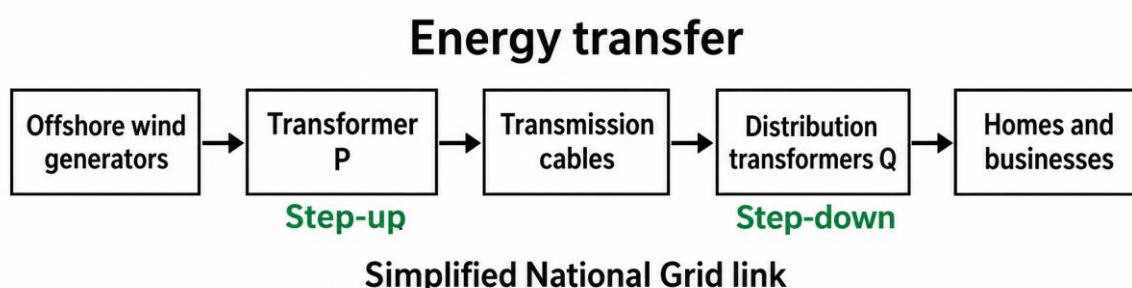


Figure 1

1(a) Name the type of transformer needed at P before long-distance transmission. **[1 mark]**

Answer / mark points: A step-up transformer. [1]

1(b) State what the distribution transformers Q do to the potential difference before electricity reaches homes. **[1 mark]**

Answer / mark points: They decrease / step down the potential difference to a much lower value suitable for domestic use. [1]

1(c) A visitor says transformer P creates extra energy because it increases the potential difference. Explain why this is wrong. **[2 marks]**

Answer / mark points: The transformer transfers energy; it does not create it. [1] For the same transferred power, the higher potential difference means a lower current, not an extra energy supply. [1]



2 Testing a pilot cable

Use Table 1. In this simplified model, the stated current and power remain steady. Resistance is the total for the complete cable path. Ignore losses in transformers and all losses except cable heating.

Table 1

Pilot quantity	Value
Power entering the cable	1.2 MW
Input potential difference	20 kV
Total cable resistance	5.0 Ω

2(a) The pilot has an input power limit of 1 300 000 W. Is 1.2 MW below this limit? Show the conversion to watts. **[1 mark]**

Answer / mark points: 1.2 MW = 1 200 000 W, below 1 300 000 W. [1 for the conversion and correct comparison]

2(b) Calculate the current in the pilot cable at an input potential difference of 20 kV. **[2 marks]**

Answer / mark points: 20 kV = 20 000 V; $I = P / V = 1\,200\,000 / 20\,000$. [1 for correct SI setup]
 $I = 60$ A. [1]

2(c) Use the current from 2(b) to calculate the power dissipated by heating in the 5.0 Ω pilot cable. **[1 mark]**

Answer / mark points: Power loss = $I^2 R = 60^2 \times 5.0 = 18\,000$ W (18 kW). [1]

Teacher prompt: The current must be squared. This is power in the cable, not the total power entering the link.

2(d) Calculate the electrical power leaving the pilot cable. Give your answer in watts. **[1 mark]**

Answer / mark points: Power out = power in – cable heating = $1\,200\,000 - 18\,000 = 1\,182\,000$ W. [1]

2(e) Calculate the energy dissipated by heating in the pilot cable during a 3.0 minute test. Give your answer in joules. **[2 marks]**

Answer / mark points: $t = 3.0 \times 60 = 180$ s. [1]
 $E = Pt = 18\,000 \times 180 = 3\,240\,000$ J. [1]

2(f) An operator calls this energy “lost”. Explain what happens to it and why it is no longer useful for supplying the town. **[2 marks]**

Answer / mark points: Electrical work increases the internal energy of the cable, which transfers thermal energy to the surroundings. [1] This dissipated energy is spread into the surroundings rather than transferred electrically to the town’s appliances. [1] It has not been destroyed.



3 Raising the transmission potential difference

The pilot is repeated at 100 kV. Power entering the cable is still 1.2 MW and total cable resistance is still 5.0 Ω . Use the same model as section 2.

3(a) Calculate the pilot cable current when its input potential difference is 100 kV. **[2 marks]**

Answer / mark points: 100 kV = 100 000 V; $I = P / V = 1\,200\,000 / 100\,000$. [1 for correct SI setup]
 $I = 12$ A. [1]

3(b) Calculate the cable heating power at 100 kV. **[1 mark]**

Answer / mark points: Power loss = $I^2R = 12^2 \times 5.0 = 720$ W. [1]

3(c) By what factor is cable heating power reduced compared with the 18 000 W loss at 20 kV? **[1 mark]**

Answer / mark points: $18\,000 / 720 = 25$, so the heating power is 25 times smaller / one twenty-fifth of its previous value. [1]

3(d) A trainee predicts that making the current five times smaller makes cable heating five times smaller. Explain the error using the power equation. **[2 marks]**

Answer / mark points: Cable heating power depends on the square of current, $P = I^2R$, not directly on current. [1] For unchanged resistance, dividing current by 5 divides heating power by $5^2 = 25$. [1]

3(e) Explain why using a high potential difference makes this transmission link more efficient. Keep the power entering the cable the same in your explanation. **[3 marks]**

Answer / mark points: At the same transmitted/input power, a higher potential difference needs a smaller current ($P = VI$). [1] The smaller current causes less cable heating / a smaller I^2R loss for the same resistance. [1] Less energy is dissipated to the surroundings, so a greater proportion of the input energy reaches the town. [1]

Teacher prompt: Do not credit “higher voltage lowers the resistance” or “there is no loss”. The same-power condition is essential.



4 Choosing the full-size cable route

The full-size link transfers 8.0 MW INTO either cable route at 100 kV. Only one route will be used. Total cable resistances are held constant. Ignore all losses except cable heating.

Table 2

Route	Length	Total resistance	Construction cost
A	45 km	20 Ω	£12 million
B	80 km	30 Ω	£8 million

4(a) Calculate the current entering either full-size cable route. [2 marks]

Answer / mark points: 8.0 MW = 8 000 000 W; 100 kV = 100 000 V; $I = P / V$. [1 for correct SI setup]

$I = 8\,000\,000 / 100\,000 = 80\text{ A}$. [1]

4(b) Calculate the heating power loss in route A. Give your answer in kilowatts. [1 mark]

Answer / mark points: Power loss = $80^2 \times 20 = 128\,000\text{ W} = 128\text{ kW}$. [1]

4(c) Calculate the heating power loss in route B. Give your answer in kilowatts. [1 mark]

Answer / mark points: Power loss = $80^2 \times 30 = 192\,000\text{ W} = 192\text{ kW}$. [1]

4(d) Calculate the electrical power leaving route A and the electrical power leaving route B. Give both answers in megawatts. [2 marks]

Answer / mark points: Route A: $8\,000\,000 - 128\,000 = 7\,872\,000\text{ W} = 7.872\text{ MW}$. [1]

Route B: $8\,000\,000 - 192\,000 = 7\,808\,000\text{ W} = 7.808\text{ MW}$. [1] Keep the unrounded answers when comparing the routes.



4 Choosing the full-size cable route continued

4(e) The operator has a £13 million construction budget and requires a cable heating loss no greater than 150 kW. Choose a route and justify your choice against both requirements. **[2 marks]**

Answer / mark points: Choose A: its £12 million construction cost is within the £13 million budget. [1] Its 128 kW heating loss is below 150 kW; B fails the loss requirement at 192 kW even though its construction cost is lower. [1]

4(f) Route A crosses a protected habitat but B does not. Give one reason why the operator might still investigate route B, despite its larger heating loss. **[1 mark]**

Answer / mark points: Avoiding damage to the protected habitat / reducing the environmental impact may justify reconsidering B or redesigning it. [1] Accept lower construction cost allowing funds for mitigation or an improved lower-resistance design. Do not claim B already meets the 150 kW limit.

4(g) A redesigned route B would carry the same 80 A. Calculate the total cable resistance that would give a heating loss of 150 kW. **[2 marks]**

Answer / mark points: $150 \text{ kW} = 150\,000 \text{ W}$; $R = P / I^2 = 150\,000 / 80^2$. [1 for correct rearrangement with SI values]
 $R = 23.4375 \, \Omega$ (accept 23.4 Ω). [1] To meet the loss limit without rounding, the resistance must not exceed 23.4375 Ω .

5 When the town uses less power

Route A is selected. Its total resistance remains 20 Ω and its input potential difference remains 100 kV. At lower demand, power entering the cable falls to 4.0 MW. Assume steady values during each stated period.

5(a) Calculate the current when the power entering route A is 4.0 MW. **[2 marks]**

Answer / mark points: $I = P / V = 4\,000\,000 / 100\,000$. [1 for correct SI setup]
 $I = 40 \text{ A}$. [1]

5(b) Calculate the cable heating power at this lower demand. **[1 mark]**

Answer / mark points: Power loss = $I^2 R = 40^2 \times 20 = 32\,000 \text{ W}$ (32 kW). [1]

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5 When the town uses less power continued

5(c) The lower demand lasts for 3.0 hours. Calculate the energy dissipated by heating in route A during this time. Give your answer in megajoules. **[3 marks]**

Answer / mark points: $t = 3.0 \times 3600 = 10\,800$ s. [1]
 $E = Pt = 32\,000 \times 10\,800 = 345\,600\,000$ J. [1]
 $E = 345.6$ MJ (accept 346 MJ or 350 MJ to 2 significant figures). [1]

5(d) At peak demand of 8.0 MW, route A dissipates 460.8 MJ in just 1.0 hour. Explain why this exceeds its energy loss over the three-hour lower-demand period. Refer to the heating powers. **[2 marks]**

Answer / mark points: Peak heating power is 128 kW compared with 32 kW: four times larger. [1]
 Energy = power $\times$ time, so one hour at four times the power dissipates more energy than three hours at the lower power. [1]

6 Checking the operator's claims

Each claim refers to the simplified model. Give precise physics reasons, not just “it is more efficient”.

6(a) “Raising the input potential difference automatically reduces the resistance of the same cable.” Explain why this is not the reason for the lower losses in section 3. **[2 marks]**

Answer / mark points: The cable resistance is unchanged in the stated comparison. [1] Current decreases because the same power is transmitted at a larger potential difference; the smaller current reduces I^2R heating. [1]

6(b) During another test, 10.0 MW enters a cable and 0.20 MW is dissipated by heating. A report says that 10.0 MW still leaves the cable because energy is conserved. Calculate the correct output power and explain the mistake. **[2 marks]**

Answer / mark points: Power out = $10.0 - 0.20 = 9.80$ MW. [1] Energy conservation includes both the electrical output and the thermal energy dissipated: $9.80 + 0.20 = 10.0$ MW. [1]

Teacher prompt: Power is an energy transfer rate. Charge/current is not “used up” to account for a power loss.

6(c) Return to route A with 8.0 MW entering it. The operator raises the input potential difference from 100 kV to 200 kV. The resistance stays $20\,\Omega$. Predict what happens to the current, the heating power and the electrical power leaving the cable. Explain each prediction. **[3 marks]**

Answer / mark points: At the same input power, doubling the potential difference halves the current: 80 A becomes 40 A. [1] The heating power becomes one-quarter as large because it depends on I^2 : 128 kW becomes 32 kW. [1] Electrical output power increases because less input power is dissipated ($8.0 - 0.032 = 7.968$ MW). [1] Numbers support the predictions but are not compulsory if the factor reasoning is explicit.

Review and improve

Ask pupils to correct one numerical setup and one causal explanation. Use “energy dissipated by heating”, not “current used up”. A higher potential difference reduces current only for the same power. Timing is an estimate awaiting classroom trial. No transformer turns-ratio or coil-power calculations are required.

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